RESEARCH HIGHLIGHTS

Technical Series 00-129

EXTENT OF CARBONATION IN BUILDINGS IN TORONTO

Introduction

Carbonation of concrete can cause serious structural problems. When it reaches reinforcing steel, the steel becomes susceptible to corrosion, and the cost of repairing corrosion damage is high. Diagnostic and preventative measures are therefore important.

Carbonation is a reaction of concrete to carbon dioxide and occurs when the pH level falls below 9.0. A literature review in the late 1980s, commissioned by Canada Mortgage and Housing Corporation (CMHC), concluded there was a significant potential for carbonation in some of the major urban centres in Canada and recommended further investigation.

CMHC subsequently commissioned this study to assess the impact of carbonation on concrete structures in Toronto.

Research Project

A total of 134 public and residential buildings were initially identified as potential candidates for testing. From these, a sample of 32 buildings was chosen and 28 were tested. The buildings, located in various parts of the Metropolitan Toronto area, represented all compass orientations. A total of 348 samples were tested.

For each building tested, core samples were taken from exposed surfaces, away from possible salt splash, in three locations: the top surfaces of balconies; vertical cast-in-place concrete columns and shear walls; and pre-cast concrete facades. To ensure that any potential surface disfigurement was kept to a minimum, cores were deliberately small, measuring 50 mm in diameter and 75 to 100 mm in length.

Immediately after drilling, the samples were placed in water to prevent further carbonation. They were then subjected to physical and chemical tests. These included splitting tensile, absorption and voids, carbonation depth, chloride-ion content and lime content.

A representative from the National Research Council provided guidance on site selection and sampling procedures, and assisted with data analysis.

Findings

The splitting tensile test determined that although the average strengths of the public buildings were slightly higher than for residential buildings, the difference was insignificant. This test revealed no correlation to carbonation and, as such, did not make a significant contribution to the findings. Absorption and voids testing also showed no clear difference between public and residential buildings, and made no significant contribution to the findings.

In assessing the depth of carbonation, four measurements were taken and averaged, because of the small size of the samples. Balcony concrete proved to be the most susceptible to carbonation, with cast-in-place vertical components next and pre-cast facades the least susceptible. No relationship was found between the age of a building and the depth of carbonation. Instead, carbonation depth emerged as a function of the quality of the concrete and possibly its constituents.

For the buildings in this study, most balconies would have had, according to code when built, 19 mm (3/4") cover; cast-in-place vertical components 38 mm (1 1/2") or 51 mm (2") cover; and precast facade panels a minimum of probably 19 mm (3/4"). For balconies, a cover of 19 mm combined with the average depth of existing carbonation derived from the samples would give a time-to-corrosion for the reinforcing steel of 82 years. However, in two buildings, corrosion depths have already been reached, and in a third of the balconies sampled, time-to-corrosion was assessed at 50 years.

It was determined that cast-in-place components in two buildings would reach 38 mm and 51 mm carbonation depths (point of corrosion) within 50 years. As well, pre-cast facade panels in two of the buildings will experience corrosion within 50 years.

CMHC SCHL

HOME TO CANADIANS

Canada

Test results indicated that all or virtually all chlorides were background chlorides present in the materials used to make the concrete. They therefore had little if any effect on carbonation. Some minor leaching or exterior chloride deposits may have occurred, but neither was of a magnitude to have any significant impact on the data.

A significant reduction in original water and lime content indicates that carbonation is taking place. Phenolphthalein is a simple, acid-base indicator test for lime content, but it is effective only to a limited depth. A thermogravimetric test augmented the phenolphthalein test to provide a more sensitive analysis of carbonation at greater depths.

Carbonation depth, as determined by phenolphthalein, appeared to be fairly superficial, as virtually all the original lime content was still present. However, thermogravimetric testing revealed significant reductions of lime content at greater depths than determined by the phenolphthalein indicator test.

Conclusions

The study showed that some of the buildings investigated will experience corrosion damage resulting from carbonation within their desired service life. Balconies in two buildings already had carbonation down to the steel reinforcements, and a third of all balconies examined had higher rates of carbonation penetration than desirable relative to service life expectancy.

None of the vertical cast-in-place components or pre-cast cladding panels had carbonation equal to cover depths. However, two buildings in each category had excessively high carbonation penetration relative to their service life expectancy.

Thermogravimetric testing showed that phenolphthalein should not be relied on for assessing lime content, as it can greatly underestimate carbonation depths. The actual time to corrosion may be significantly less than predicted by the simple indicator test. Thermogravimetric testing, or other tests perhaps, is therefore essential for determining carbonation depths.

The drilling and testing procedures used proved to be technically sound and economic. The splitting tensile and absorption and void data were beneficial in confirming the absence of anomalies in other data. Given that these tests did not otherwise make a significant contribution to the findings, they are not considered essential for future field studies. The chloride-ion content test also eliminated the possibility of anomalies. In future studies, it would not be necessary to use this as a primary test, but it could be reserved for second-stage testing, if initial carbonation tests indicate further testing is necessary.

Project Manager: A. J. Houston

Research Report: *Extent of Carbonation in Buildings in Toronto, 1990*

Research Consultant: John A. Bickley Associates Ltd.

A full report on this project is available from the Canadian Housing Information Centre at the address below.

Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

The **Research Highlights** fact sheet is one of a wide variety of housing-related publications produced by CMHC.

For a complete list of **Research Highlights**, or for more information on CMHC housing research and information, please contact:

The Canadian Housing Information Centre
Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, ON K1A 0P7

Telephone: 1 800 668-2642
FAX: 1 800 245-9274

OUR WEB SITE ADDRESS: www.cmhc-schl.gc.ca/Research